Eur J Vasc Endovasc Surg **17**, 213–218 (1999)
Article No. ejvs.1998.0743

Complications in Carotid Endarterectomy are Predicted by Qualifying Symptoms and Preoperative CT Findings

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Objectives: *to relate the 30-day perioperative rate of stroke or death in Carotid endarterectomy (CEA) to preoperative qualifying symptoms and to the presence of cerebral infarction (CI) demonstrated on computed tomography (CT).*
Design: *retrospective clinical study.*
Material and methods: *two hundred and seventy-two consecutive CEAs for symptomatic stenosis in 262 patients were analysed.*
Results: *the total complication rate was 5.9%. Patients with retinal symptoms (n=81) had no complications, TIA patients (n=76) had 6.6% (p<0.001). Patients qualifying with minor stroke (n=113) had complications in 9.7% (n.s. compared to TIA patients). Patients qualifying with cortical symptoms had a significantly higher complication rate compared to those with retinal (8.4% vs. 0%, p=0.004). The presence of a preoperative CT-verified infarction resulted in a higher risk for stroke or death (9.8% vs 2.8%, p=0.008). Within the subgroup presenting with minor stroke, the presence of CI resulted in stroke or death in 13.9%. In patients without CI the corresponding figure was 2.4% (p=0.017).*
Conclusion: *the qualifying symptoms and the presence of CI visualized by CT influence the complication rate in CEA. When evaluating risk and comparing outcome, these parameters should be included in reporting standards.*

Key Words: Carotid endarterectomy; Complications; Computed tomography; Stroke.

Introduction

The question of whether carotid endarterectomy (CEA), in addition to the best available medical treatment, is beneficial to any group of patients was answered with the publication of the interim results of the ECST study[1] and of the NASCET study[2] in 1991. Both studies focused on symptomatic stenotic lesions and concluded, even though their methods of determining degree of stenosis differed, that endarterectomy was beneficial provided the diameter reduction of the stenotic lesion was severe.

Although the degree of stenosis is a definite risk factor for future stroke, additional factors also influence the risk. The NASCET study concluded that the risk of a future stroke in the non-operated group was associated with the burden of several risk factors whereas no such correlation could be shown in the surgically treated group.[2] Different presenting symptoms also appear to carry varying risk rates for future ipsilateral stroke in unoperated patients.[3]

The symptoms commonly accepted as indications for CEA as secondary stroke prophylaxis (within 4–6 months) are non-disabling (minor) stroke, transient ischaemic attacks (TIA) and retinal emboli (retinal infarction or amaurosis fugax). Until recently these qualifying symptoms have not been dealt with separately in reports considering surgical outcome. This is surprising since several previous studies have concluded that the rate of complications in connection with CEA is influenced by the type of qualifying symptom.[4–9] The recently published systematic review by Rothwell *et al*. also points out that there is a significant difference in the rate of stroke or death in patients who qualify for surgery because of ocular ischaemia as compared to those with cerebral transient ischaemic attack or stroke.[10]

Although the connection between degree of stenosis and indication for carotid endarterectomy is clear in symptomatic patients, it is logical to assume that if concomitant risk factors could be taken into account there could be a group within the "severe stenosis" category that does not benefit from surgery. According to the same reasoning some patients in the "moderate stenosis" group could be better off if undergoing

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1078–5884/99/030213+06 $12.00/0

surgery. In the present study, a risk analysis was performed in order to assess whether the perioperative rate of stroke or death within 30 days was influenced by qualifying events in a 5-year clinical material of symptomatic patients. Secondly, we investigated whether positive findings on preoperative computed tomography of the brain (CT) were of prognostic value in predicting the risk of perioperative stroke or death.

Methods

A retrospective study was performed including all patients operated for symptomatic carotid stenosis during the period of 1990–1994 at the Department of Surgery, Karolinska Hospital. The register of operations was used to identify the patients. Their records from the surgical and neurological departments were subsequently examined. All patients had a follow-up for a minimum period of 1 month. Data were extracted according to a standardised protocol including qualifying symptom, concomitant diseases, degree of stenosis as measured by angiography with the ECST method, findings on preoperative CT investigation, operative procedure and postoperatively registered complications. The patients' preoperative neurological characteristics were retrospectively classified according to the CHAT system.[11] The findings in the preoperative CT investigation were judged according to the original report from the department of neuroradiology. In accordance with the CHAT system, findings were categorised as: T0 – no lesion, T1 – appropriate lesion, T2 – lesion only in another vascular territory, or T3 – combined, appropriate lesion and lesion in another vascular territory. In four cases, the original CT report could not be retrieved. These patients were subsequently excluded from the analysis of CT findings. No complications were connected with these cases. Concomitant risk factors were recorded according to the Subcommittee on Reporting Standards for Cerebrovascular Disease of the Society for Cardiovascular Surgery.[12] In tables presenting risk factors, categories 1–3, according to these standards are considered positive.

In the analysis the patients were divided into groups depending on the qualifying event according to the following definitions. Amaurosis fugax: impaired vision judged to be of embolic nature and resolved within 24 h. Retinal infarction: same symptom as previous but not resolved within 24 h. Transient ischaemic attack (TIA): focal cortical neurological deficit judged to be of embolic nature and resolved within 24 h. Minor stroke: focal neurological deficit not resolved within 24 h, yet not necessitating help in activities of daily life. Patients with qualifying symptoms within more than one of the above categories were classified according to the most severe symptom (retinal<TIA<minor stroke).

With regard to perioperative complications, any new or extension of an existing focal cerebral deficit (or amaurosis fugax, none observed) as well as death of any cause within 30 days was registered. The same definitions as above were used, with the addition of disabling stroke, defined as a neurological deficit exceeding 24 h which necessitated help in activities of daily life. In the analysis of perioperative complications any stroke or death, regardless of cause, within 30 days was considered as a perioperative complication. All patients were examined pre- and 30 days postoperatively by the neurologist as well as by the surgeon on separate occasions. In the few cases where there was a discrepancy between the interpretation by the surgeon and the neurologist in the records concerning preoperative classification as well as perioperative complication, the opinion of the neurologist was preferred. Two-tailed Fishers' exact test or Chi-squared test, as appropriate, was used for statistical evaluation of differences between groups. A p value of <0.05 was considered significant.

Patients

All 262 patients operated with CEA for symptomatic carotid stenosis >50% (272 operations) at the vascular unit, Department of Surgery, Karolinska Hospital during 1990–1994 were included. The indication for surgery was retinal symptoms in 81 cases (29.8%, 67 amaurosis fugax and 14 retinal infarction), TIA in 76 (27.9%) and minor stroke in 113 cases (41.5%). Two operations (0.7%) were performed for a haemodynamic indication (global ischaemia).

One hundred and seventy-eight of the patients were men (65.4%). The median age was 69 (39–83) years for both males and females. The sex and age distribution was equal in the subsequently analysed groups (retinal vs. TIA vs. minor stroke and CT infarction vs. no infarct). Fifty-three per cent of operations were on the left and 47% on the right. The indication for surgery in relation to the degree of stenosis and the proportion of CT verified CI (CHAT T1–3) is shown in Figs 1 and 2, respectively. The distribution of concomitant diseases and generally appreciated risk factors according to qualifying symptom are shown in Table 1. The distribution of the same parameters according to the preoperative CT findings are shown in Table 2.

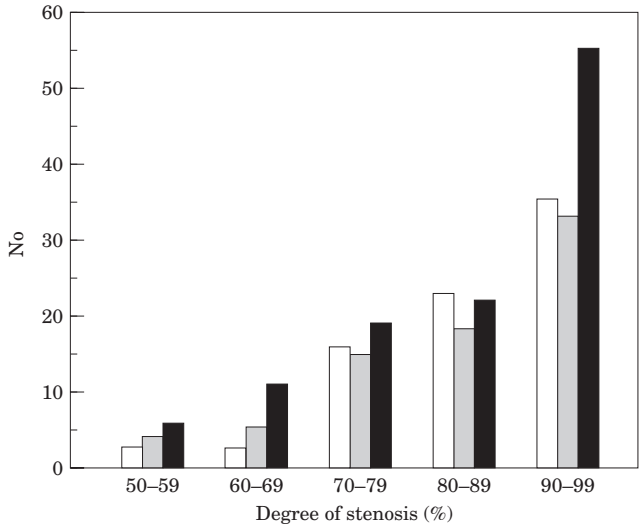

Fig. 1. Number of patients according to severity of stenosis and qualifying symptom. (□) Retinal; (▨) TIA; (■) minor stroke.

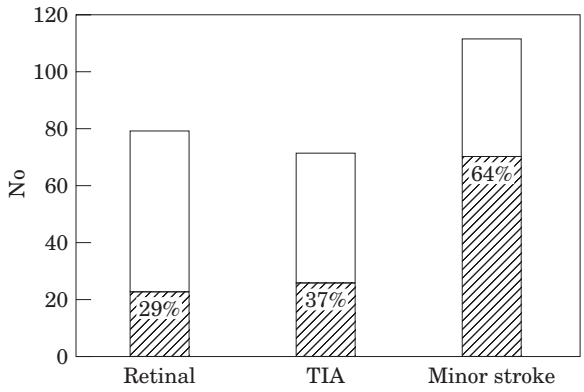

Fig. 2. Infarction on preoperative computerised tomography according to qualifying symptom. (□) CT−; (▨) CT+.

Patients with retinal symptoms, TIA, or minor stroke, judged to be of embolic origin, with an ipsilateral carotid stenosis exceeding 50% as measured by the ECST method, were considered for surgical treatment. Patients with a stenosis between 50 and 69% were randomised to surgery in the ECST. All patients considered for operation were discussed, on a formal basis, in a group consisting of a neurologist, vascular surgeon, clinical physiologist and neuroradiologist. The consensus principle was applied.

Operation on patients with minor stroke was postponed until 6 weeks after the qualifying symptom. It is noteworthy that six of these patients experienced new, but less severe, symptoms during that time. Since the inclusion criteria for the study was CEA, severe strokes during the same period were not noted.

Surgery

Surgery was performed by one of five vascular surgeons with the patient under general anaesthesia with isoflurane, kept normokapnic and normotensive with the aid of nitroglycerine and dopamine when needed. An indwelling shunt (Pruitt–Inhara) was used in 204 operations (74%). In the early part of the period the shunt was used routinely. In the later part of the study the decision to shunt was made on the basis of perioperative transcranial Doppler surveillance (middle cerebral artery mean velocity decrease of >60% at clamping).[13] Patch-closure (vein or Dacron) was performed in 72% and sutures to tack down the distal intima were used in 32%. Postoperatively all patients were continuously observed in the postoperative ward at least until the following morning with intra-arterial pressure monitoring. The patients were routinely treated with 75 mg of salicylic acid unless anticoagulation was indicated for cardiac pathology.

Results

The total number of complications recorded within 30 days was 16/272 (5.9%). Nine patients experienced a minor stroke (3.3%), two of which resolved completely within 3 weeks. Six patients suffered a disabling stroke (2.2%), of whom three subsequently died (1.1%), and one additional patient who did not experience any

Table 1. Risk factor distribution according to indication for surgery.

	Retinal $n=81$			TIA $n=76$			Minor stroke $n=113$		
	Data available	*n*	%	Data available	*n*	%	Data available	*n*	%
Diabetes	81	8	9.9	76	10	13.2	113	29	25.7
Tobacco use	80	51	63.8	74	35	47.3	113	58	51.3
Hypertension	81	51	63.0	76	43	56.6	113	65	57.5
Hyperlipidaemia	72	30	41.7	71	34	47.9	104	45	43.3
Cardiac disease	81	39	48.1	76	44	57.9	112	52	46.4
Renal insufficiency	80	9	11.2	73	5	6.8	110	8	7.3
Pulmonary disease	81	11	13.6	76	4	5.3	112	11	9.8

Table 2. Risk factor distribution according to preoperative findings on computerised tomography.

	No infarct $n=145$ Data available	*n*	%	Infarct $n=123$ Data available	*n*	%
Diabetes	145	22	15.2	123	26	21.1
Tobacco use	142	76	53.5	123	66	53.7
Hypertension	145	76	52.4	123	71	57.7
Hyperlipidaemia	133	60	45.1	112	49	43.4
Cardiac disease	145	68	46.9	122	65	53.3
Renal insufficiency	141	11	7.8	120	11	9.2
Pulmonary disease	144	11	7.6	123	15	12.2

Table 3. The pattern of perioperative stroke and death.

Complication	Total	Preoperative symptoms TIA	Minor stroke
		() = Lethal complication	
Ipsilateral infarction	10	4 (1)	6
Bilateral infarction	1	0	1 (1)
Contralateral infarction	2	1 (1)	1
Haemorrhage (hyperperfusion)	2	0	2
Cardiac death (no neurology)	1	0	1 (1)

complication directly connected to the carotid operation died within 30 days of a myocardial infarction related to a subsequent operation for critical limb ischaemia (0.4%). The total mortality was thus four (1.5%), non-fatal disabling stroke three (1.1%) and non-disabling strokes with residual symptoms at 30 days seven (2.6%). Table 3 illustrates the type of complication and its association to qualifying symptom. There was no statistically significant difference in complication rate between men and women. Within the female group, four operations resulted in stroke or death (4/94, 4.3%) and in the male group the corresponding figures were 12/178 (6.7%). The 16 complications were evenly distributed among the patients operated for left and right carotid artery stenosis. Regarding concomitant risk factors, the most pronounced difference between the groups was the uneven distribution of diabetes: 9.9% for patients qualifying with retinal symptoms vs. 20.6% for cortical symptoms ($p<0.05$). However, when diabetes was analysed as an independent risk factor for complications there was no statistically significant difference.

Stroke or death according to qualifying symptom

In the group of patients with qualifying retinal symptoms, two TIAs were recorded but no complications according to the above outlined criteria. In the group of patients qualifying with TIAs there were 5/76 (6.6%) stroke or death. Comparing the group with retinal symptoms to that with TIAs revealed a highly significant difference in the rate of stroke or death ($p<0.001$). Comparing patients with retinal to those with cortical symptoms of any severity (TIAs as well as minor strokes) showed a significant difference in stroke or death rate: 0/81 vs. 16/189 ($p<0.01$). The rate of stroke or death in the group whose indication was minor stroke was 11/113 (9.7%), and thus was higher than for the TIA group, but this difference was not statistically significant.

CT findings vs. stroke or death

A CT verified infarct was found to be associated with a significantly increased rate of stroke or death compared to patients with no demonstrable lesion; 12/123 (9.8%) vs. 4/145 (2.8%), $p<0.01$. If only lesions categorised as appropriate (CHAT T1 + T3) were considered, a significant difference was still found ($p<0.05$). Excluding the patient who died without any neurological complication did not alter the significance. When CT findings vs. complications were analysed within the subgroups according to qualifying symptom, no significant influence of CT findings was demonstrated within the amaurosis fugax or TIA groups. However, for patients with minor stroke, a significantly higher rate of stroke or death was found in the group with CT verified infarcts compared to

Table 4. Complications 0–30 days in relation to qualifying symptom and preoperative CT findings. CT positive defined as CHAT T 1–3.

Indication	No infarct	Infarct	CT data unavailable	Total
Retinal	0/57	0/23	0/1	0/81
TIA	3/46 (6.5%)	2/27 (7.4%)	0/3	5/76 (6.6%)
Minor stroke	1/41 (2.4%)	10/72 (13.9%)		11/113 (9.7%)
Haemodynamic	0/1	0/1		0/2
Total	4/145 (2.8%)	12/123 (9.8%)	0/4	16/272 (5.9%)

patients with no lesion; 10/72 (13.9%) vs. 1/41 (2/4%), $p<0.05$ ($=0.017$). Complications are summarised in Table 4.

Discussion

One of the early empirical risk assessment methods for predicting the complications of CEA was the version of Sundt *et al*. in which patients were grouped in one of four categories based on neurological stability, medical and angiographic risk factors.[14] Another model has been presented by McCrory *et al*. in which it was possible to predict the inhospital complication rate according to the presence of a number of risk factors extracted from the clinical records of the patient.[15] None of these models used CT verified infarctions. However, all patients treated with CEA in our hospital undergo preoperative CT investigation. Earlier studies have shown that patients with clinical stroke are subject to greater operative risks than those with TIA or amaurosis fugax.[9,16–19] On the other hand, Kearse *et al*., for example, were not able to show any significant relation between preoperative cerebrovascular symptoms on EEG abnormalities and the presence of EEG ischaemic pattern changes at carotid artery cross-clamp.[20] In the review by Rothwell *et al*.[10] no overall difference in the perioperative risk of stroke and death was found in patients operated on for stroke compared to those operated for TIA. They concluded that the real dichotomy is not between TIA and stroke but between ocular and cerebral ischaemia, a conclusion which is in accordance with the results in the present study.

Patients with CT verified infarctions in the group with retinal symptoms were few compared to those with cortical symptoms. The difference in complication rate between patients qualifying for CEA by retinal symptoms compared to those with cortical is in accordance with the findings of other investigators.[5,10] It has also been established that patients with clinical stroke more often have CT verified infarctions than patients with retinal or transient cortical symptoms.[21] An important observation in this study is the significant difference in complication rate within the group qualifying for surgery by minor stroke, depending on whether the preoperative CT investigation revealed an infarction or not. Our results suggest that CI visualized by CT is an important risk factor to take into account when considering preoperative risk evaluation. Our findings are in accordance with those of Cao *et al*. who demonstrated a correlation between CT verified CI and the perioperative risk of stroke or death. However, that study included asymptomatic as well as symptomatic patients. Subanalysis was performed for the asymptomatic group but not for the various groups of symptomatic patients.[21] Our results are also in accordance with those of Graber *et al*. who found a significant increase in risk for non-stroke patients in whom an infarction was shown on a preoperative CT.[22] Other authors have come to the opposite conclusion concerning the importance of visualised infarctions but these studies deal with early CEA in stroke patients.[23] None of the patients in the present study were operated within 6 weeks of a minor stroke.

It is reasonable to believe that the presence of a brain infarction on CT should be taken into account when stratifying patients into studies or when comparing results from different centres regarding clinical outcome after CEA. The 30-day complication rate of 5.9%, including all strokes and death of any cause, in the present study is in accordance with the results of the ECST and NASCET studies and with the review of Rothwell *et al*. from 1996.[24] The results within the subgroups of patients were, however, quite different. A complication rate of 13.9% in the group of minor stroke patients with a CT verified infarction is worrying but might be reasonable assuming that these patients are at greater risk if left unoperated. Earlier investigations addressing the recurrence rate after minor stroke suggest a positive risk-benefit balance favouring surgery even allowing for this high complication rate. Mansour *et al*. reported an annual incidence of 8–11%,[25] Hier *et al*. a 2-year cumulative rate of 14.1%,[26] and Sacco *et al*. 42% cumulative rate for

men and 24% for women over 5 years with 17.9% occurring during the first year.[27] According to these figures, it still seems beneficial to recommend surgery for patients with minor stroke even in the presence of a CT verified infarct. On the other hand an operative complication rate of 0% for the amaurosis fugax group is impressive but the benefit of the operation is diminished by the fact that this group, if left unoperated, has a more benign prognosis than those with cortical symptoms such as TIA.[5] The most common cause of perioperative stroke is thought to be embolisation.[28–30] One might speculate over what mechanism is responsible for the increased risk of perioperative stroke found for patients with positive preoperative CT scans. The vulnerability of the penumbra zone around a CI suggests that perioperative hypoperfusion could be responsible for further infarction. Another explanation could be that the impaired regional cerebral circulation makes these patients more susceptible to cell damage as a result of embolisation.

In conclusion, preoperative symptoms – cortical or retinal – have a statistically significant impact on the surgical complication rate. The presence of a CI assessed by CT also increases the perioperative risk. We therefore suggest that studies presenting the results of CEA subgroup patients according to these factors.

Acknowledgements

This study was supported by grants from the Swedish Stroke Association and from the Swedish Heart-Lung Foundation.

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Accepted 14 August 1998